Rachel Montgomery, on behalf of the CLAS12 RICH Group:
CEBAF Upgrade at Jefferson Lab

JLab 12GeV Upgrade:
- Shutdown 2012
- Electron beam 6GeV to 12GeV
- Upgrade existing, install new detectors; new hall
- First beam delivery **Feb 2014**

Max $E = 10.9 \text{GeV}$, Max $I = 90 \mu \text{A}$
Luminosity $10^{35} \text{cm}^{-2} \text{s}^{-1}$
Longitudinal polarization = 75-85%

https://www.jlab.org/12-gev-upgrade
Hall B, CLAS → CLAS12: Polarised/unpolarised lepton scattering experiments with close to full angular coverage

CLAS12 Physics Program:
- **Internal nucleon dynamics**, 3-D imaging of the nucleon; mapping of TMDs and GPDs
- Good separation of π, K, p over the full kinematics $2 - 8 \text{ GeV}/c$ necessary!
  - π/K separation of $\sim 4\sigma$ up to $8 \text{ GeV}/c$
  - **RICH**

<table>
<thead>
<tr>
<th>Physics Program</th>
<th>Particle Identification Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal nucleon dynamics</td>
<td>Flavour tagging</td>
</tr>
<tr>
<td>Quark hadronisation in nuclear medium</td>
<td>Constraining models</td>
</tr>
<tr>
<td>Spectroscopy</td>
<td>Rare processes</td>
</tr>
</tbody>
</table>

Rossi, P. (2011), CLAS12 2\textsuperscript{nd} European Workshop, Paris, March 2011
• 6 Radial Sectors:
  • Each with: 1.2m gap; ~6m² entrance window

• Hybrid Imaging RICH:
  • Aerogel radiator, visible light photon detectors
  • Focussing mirror system → minimise: detection area, cost, influence on TOF
**Direct Case (proximity):**
- $\theta<12^\circ$, $p = 3 - 8\text{GeV/c}$

**Reflected Case:**
- $\theta>12^\circ$, $p = 3 - 6\text{GeV/c}$
Simulation Studies:
- **Geant4** framework
- **Pattern reconstruction**: Maximum Likelihood, ray tracing ansatz

**Requirements:**
- **Direct** case, aim: 8GeV/c π/K separation 5.5mrad
  - require 7 detected photoelectrons
- **Reflected** case, at least 3 detected pe’s for algorithm
Photon Detectors – Requirements, Hamamatsu H8500

<table>
<thead>
<tr>
<th>MAPMT Parameter</th>
<th>H8500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Area (mm x mm)</td>
<td>49 x 49</td>
</tr>
<tr>
<td>Number of Pixels</td>
<td>64 (8 x 8)</td>
</tr>
<tr>
<td>Pixel Size (mm x mm)</td>
<td>5.8 x 5.8</td>
</tr>
<tr>
<td>Packing Fraction (%)</td>
<td>89</td>
</tr>
<tr>
<td>Range (nm)</td>
<td>260 - 650</td>
</tr>
</tbody>
</table>

**Requirements:**
- Position sensitive
- Pixel sizes $< 1\text{cm} \times 1\text{cm}$
- Efficient single photon detection crucial
- High packing fraction
- Sensitivity to visible light

✔ Hamamatsu H8500 MAPMT
Detector Characterisations:

- Uniformity studies
- Single photon signal losses
- Crosstalk studies
- H9500, H7546 amongst tested

15% loss of SPE signal
Photon Detectors – Single Photoelectron Scans

0.04mm steps

0.05mm steps

0.5mm steps
Radiator Material: **Aerogel (n=1.04 to 1.06)**

- Momentum range (2 – 8 GeV/c)
- Constrained depth, low-material budget

- **Characterise optical properties:** reflected case and MC input

- **Refractive index** (prism method), **transmittance** (spectrophotometer), **thickness profile** (coordinate machine)

- Novosibirsk, Matsushita tiles

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**Snell-Descartes Law**

\[
\delta = \gamma - \beta + \arcsin\left( n \sin \beta \arcsin\left( \frac{\sin \gamma}{n} \right) \right)
\]

- Red laser (n=1.0516)
- Green laser (n=1.0523)
- Blue laser (n=1.0531)

**Hunt Formula Fit**

M. Hoek, J. Phillips, Uni. Glasgow
Cosmic Prototype for MAPMT Simulation Model Validations

- Scintillator Bars
- Matsushita Aerogel $n=1.05$
- H8500 Single Channel PMTs
- 800mm
- 54mm
- Muon

- Geant4 Simulation
- Aerogel
- Cherenkov Light
- H8500 MAPMT

- Y-ID
- X-ID
- Signal Charge (QDC Bins)

Data

R. A. Montgomery, 17/06/13
### Background Corrected Yields:

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Algorithm</th>
<th>Aerogel Yield (NPE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1cm</td>
<td>Cluster</td>
<td>9.22 ± 0.29</td>
</tr>
<tr>
<td>1cm</td>
<td>Template</td>
<td>10.26 ± 0.26</td>
</tr>
<tr>
<td>2cm</td>
<td>Cluster</td>
<td>12.87 ± 0.24</td>
</tr>
<tr>
<td>2cm</td>
<td>Template</td>
<td>13.99 ± 0.24</td>
</tr>
</tbody>
</table>

n.b. 10% uncertainty from gain calibration

### Data Vs Sim:

- Muon hit in MAPMT window well-modelled
- Aerogel yield requires pixel single photon resolution variations

Muon Signal Charge (1cm) <NPE> = 30

Aerogel Yield (1cm)
Prototype Studies at Testbeams

- **CERN PS East Area, T9 beam test area** (Jul-Aug 2012 and Nov-Dec 2012):

  - Primary beam: \( p^+ \rightarrow p^{-} \), \( \pi^+ \rightarrow \pi^{-} \), \( K^+ \rightarrow K^{-} \), \( e^+ \rightarrow e^{-} \)
  - Momentum: \( 0 \rightarrow 15 \text{ GeV/c} \)

  **Testbeams:**
  - Negative polarity; momenta 6, 7, 8 \( \text{GeV/c} \)
  - At 8 \( \text{GeV/c} \), \( \pi:K \sim 60:1 \)

![Diagram of beam test area and testbeam setup](image-url)
Prototype detector Setup – Direct Light Configuration

Side View:

Aerogel

1000mm

Cherenkov Light

Ring of MAPMTs

Beam

MAPMTs:
• 28 H8500 MAPMTs (14 normal, 14 UV-extended windows)
• Readout MAROC3 electronics (ADC)

Aerogel (Novosibirsk):
• Varying n, thickness, transparencies
• Transparency monitored – laser and photodiode

R. A. Montgomery, 17/06/13
Prototype detector Setup – Direct Light Configuration

- 8 GeV/c, \( n = 1.04 \), \( t = 2 \text{cm} \)
- 20k events

- 8 GeV/c, \( n = 1.06 \), \( t = 2 \text{cm} \)
- 20k events
Prototype detector Setup
– Reflected Light Configuration

- **Absorbers**: Novosibirsk, CERN AMS samples
- $n=1.05$, $t=2\text{cm}$, varying transparency
Radiator n=1.05, t=6cm; Beam p = 6GeV/c: Comparison with and without absorbers:
CLAS12:

Components Testing:

Cosmic Stand:

Testbeams:

Outlook:

- Technical design report currently underway
- Completion and installation of one complete RICH sector planned for beginning of CLAS12 data taking
Thanks for your Attention

...Any Questions?